Chapter 1: Introduction

Definition of Bottomland Hardwoods

The term "bottomland hardwoods" is generally used to describe both the dominant forest tree species and the major forest types that occur on floodplains in the lower Midwest and the southeastern United States. Occasionally, the term is also applied to floodplain forests in other regions. Bottomland hardwoods in much of the scientific literature, and in this guide, include not only the hardwood species that predominate in most forested floodplains but also the softwood species such as baldcypress. The Society of American Foresters' forest cover type classification system (Eyre, 1980) identifies 16 forest cover types found in the southern and central United States (see Appendix A for descriptions) that are considered bottomland hardwoods (table 1.1).

In this guide, bottomland hardwoods are treated as wetlands. Under the wetlands classification system used by the U.S. Fish and Wildlife Service (Cowardin and others, 1979), bottomland hardwoods are in the palustrine system, forested wetland class, and primarily either in the broad-leaved deciduous or needle-leaved deciduous subclasses. It is recognized, however, that not all bottomland hardwoods may be classified as jurisdictional wetlands under the jurisdiction of section 404 of the Clean Water Act (U.S. Army Corps of Engineers, 1987), as there are several methodologies for identifying wetlands. Regardless of whether or not a particular project involves jurisdictional wetlands, the basic principles described in this text will remain the same.

Table 1.1. Bottomland hardwood forest cover types.[1]

Type	SAF Number[1]
River birch-Sycamore	61
Silver maple-American elm	62
Cottonwood	63
Pin oak-Sweetgum	65
Willow oak-Water oak-Laurel (diamondleaf) oak	88
Live oak	89
Swamp chestnut oak-Cherrybark oak	91
Sweetgum-Willow oak	92
Sugarberry-American elm-Green ash	93
Sycamore-Sweetgum-American elm	94
Black willow	95
Overcup oak-Water hickory	96
Baldcypress	101
Baldcypress-Tupelo	102
Water tupelo-Swamp tupelo	103
Sweetbay-Swamp tupelo-Redbay	104

[1] Numbers refer to the classification system used by the Society of American Foresters (SAF). See Eyre (1980) and Appendix A for cover type descriptions.

The common and scientific names, along with information on habitat, flood and shade tolerance, seed ripening and storage requirements, and reproductive characteristics of many tree species common to southern bottomland hardwood forests are given in Chapter 4. Table 13.2 contains the common and scientific names of some wildlife species common in bottomland hardwood forests. In addition, Appendix B lists the common and scientific names of all species mentioned in the text.

Geographic Scope

This guide is designed primarily to provide information for restoration efforts in the lower Midwest, including the Lower Mississippi Alluvial Valley (LMAV; extending from the southern tip of Illinois to the Gulf of Mexico and including portions of Illinois, Missouri, Kentucky, Tennessee, Arkansas, Mississippi, and Louisiana) and the southeastern United States (fig. 1.1). The area with perhaps the greatest forested wetland losses and potential for restoration is the delta portion of Arkansas, Louisiana, and Mississippi. To a lesser degree, the methods described here will be applicable to forested wetlands throughout the United States.

What is Restoration?

Throughout this guide, "restoration" refers to the ultimate goal of bottomland hardwood reestablishment projects. It is therefore necessary to discuss the concept of restoration and contrast it with other commonly used terms, such as "reforestation," "reclamation," "creation," and "enhancement."

Ecological restoration is defined as the return of an ecosystem to a close approximation of its condition prior to disturbance (National Research Council, 1992). This definition, supported by the Society for Ecological Restoration, stresses that restoration is intentional and that it emulates the structure, function, diversity, and dynamics of a previously existing natural ecosystem. The Natural Resources Conservation Service (NRCS) defines a restored wetland as "a rehabilitated degraded wetland where the soils, hydrology, vegetative community, and biological habitat are returned to the original condition to the extent practicable" (NRCS, 1998). The NRCS's definition recognizes that it may not always be possible to completely restore a site to some previous condition, but that it is still desirable to restore it to the greatest extent possible.

These definitions of restoration serve to highlight some of the difficult issues facing restorationists. Although the definitions are seemingly straightforward, questions about what constitutes predisturbance or original forest conditions are ambiguous and need to be considered because they are often open to debate within

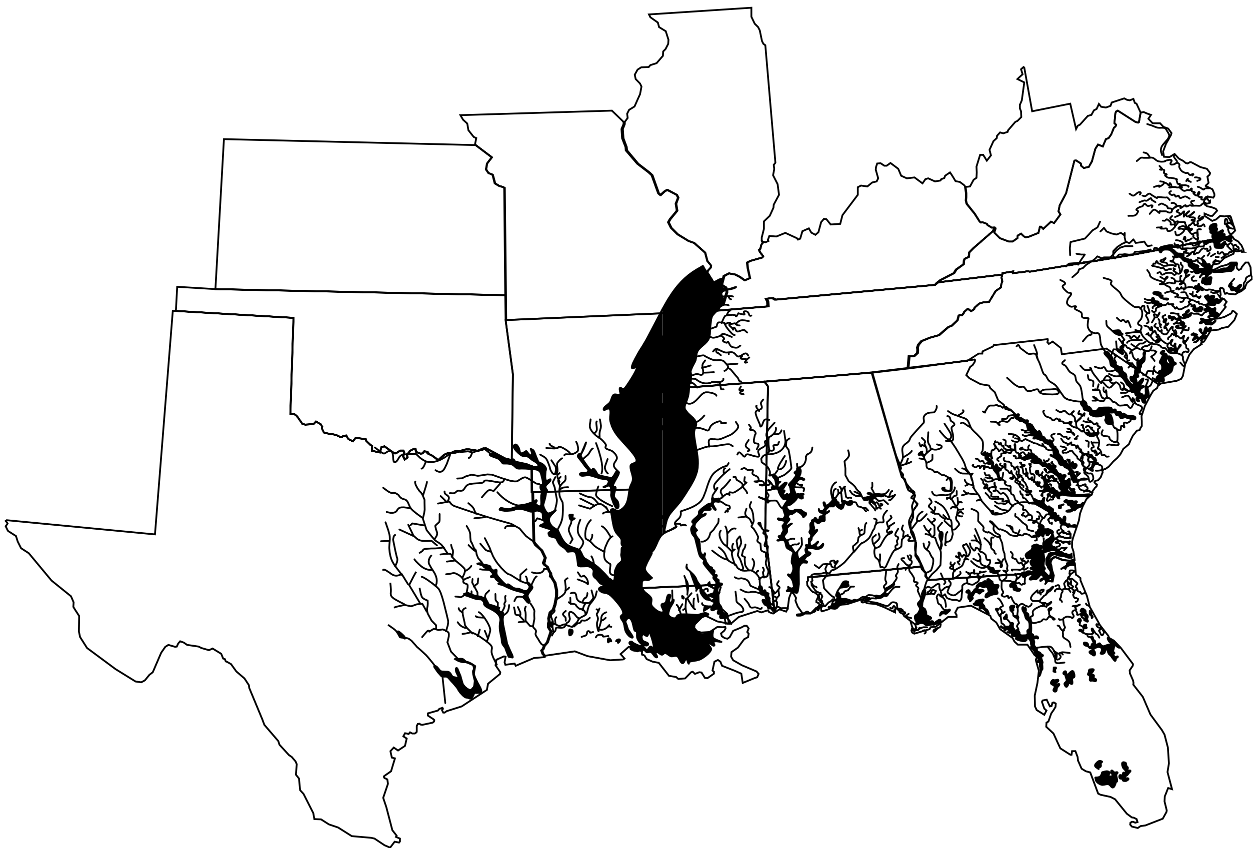

Figure 1.1. Distribution of bottomland hardwood forests along rivers and streams in the lower Midwest and southeastern United States. The dark band shows the extensive area covered by this forest type along the lower Mississippi River (modified from Putnam and others, 1960).

the scientific community. During the height of Pleistocene glacial activity, the forests of the southeastern United States included many boreal forest species such as spruce and fir (Delcourt and Delcourt, 1987). While it may be obvious that we should not try to restore to the Pleistocene community type, it is often not so obvious that forests have been naturally changing for eons and will continue to do so. Factors that have shaped the structure, function, diversity, and dynamics of bottomland hardwood forests over the last 500 years (less than the lifespan of some individual trees in the region) include natural disturbances (e.g., hurricanes, droughts, lightning-caused fires), Native Americans' agricultural practices and use of fire, and the agricultural, silvicultural, drainage, and flood control practices of European settlers. Restorationists need to be aware that, in a sense, they are trying to hit a moving target. Trying to restore to a previously existing natural ecosystem is less important than matching the tree species to be planted with the topographic, soil, and hydrologic conditions that will exist on the site after the project is completed. We must, therefore, use best judgement and any available data to determine the composition and structure of the forests we want to restore.

True ecological restoration may not be possible in many cases because of factors beyond the restorationist's control. For example, Schneider and others (1989) have shown that practically every major stream and hundreds of smaller ones throughout the southeastern United States have been affected by major construction projects. Such projects often affect the timing, magnitude, and duration of flooding as well as groundwater dynamics (i.e., a site's hydrology). Ideally, restorationists would be able to restore the hydrologic regime of their restoration sites, but it is rarely possible to reverse the impacts of major construction projects that affect hundreds or thousands of square kilometers of land. Because hydrology drives wetland ecosystems and determines the type of wetland that will develop, it must be restored if possible. If complete hydrologic restoration cannot be accomplished, then the trees to be planted must be selected based on the expected hydrologic regime. If only the hydrology is restored (a partial restoration), the vegetation and soils will develop naturally over a period of many years (and eventually become a full restoration).

The lack of ability to conduct a full restoration does not eliminate the importance of restoring those functions and values that we understand or restoring an area as close as possible to its previous condition. Restorationists, then, may frequently have to settle for more modest goals than complete ecological restoration, such as partial restoration or one of the terms described below: reclamation, reforestation, creation, or enhancement. Regardless of the level of restoration, the restorationist should maintain a holistic approach to each project and, to the greatest extent possible, establish an ecological community that is not only as close as possible to the original forest but is also well matched to the environmental conditions that will exist on the completed site.

Reclamation is defined by Jordan and others (1988, p. 55) as "any deliberate attempt to return a damaged ecosystem to some kind of productive use or socially acceptable condition short of restoration." Reforestation is defined by the Society of American Foresters (SAF) as the reestablishment of a tree crop on forest land (Ford-Robertson, 1971). With reforestation there is not necessarily any attempt to restore the same species of trees or the same functions that occurred naturally on the site. Establishment is defined as the process of developing a crop to the stage where it can be considered safe from normal adverse influences such as weeds, browsing, or drought (Ford-Robertson, 1971). Without hydrologic restoration, most projects probably fall within the realm of reforestation or reclamation. On any project, the restorationist is faced with the decision to spend a limited budget to completely restore a small amount of land or to reforest a much larger area.

Wetland creation has two meanings. First, it is "the conversion of a persistent non-wetland area into a wetland through some activity of man" (Lewis, 1990, p. 418). This activity generally includes lowering the surface of an upland sufficiently for the seasonal or permanent exposure of the water table. Conversely, wetland creation can be accomplished by filling a deepwater habitat with dredged materials to a sufficiently shallow depth to support wetland plants. The second kind of wetland creation occurs when an entire ecosystem is first destroyed and then re-created on the same site. Creation in this manner takes place, for example, when a wetland is destroyed during the course of surface mining. Following mining, the original ecosystem is re-created on physically reclaimed land, which requires the ecological engineering of new soils and hydrological conditions, as well as the establishment of a biotic community. The term "constructed wetland" is often used interchangeably with "created wetland" and is apparently coming into preferred usage by many practicing restorationists.

Enhancement is defined as "the increase in one or more values of all or a portion of an existing wetland by man's activities, often with the accompanying decline in other wetland values" (Lewis, 1990, p. 418). Examples of forested wetland enhancement include selective removal of some tree species to favor growth of those species that provide greater values to desired wildlife and diking tracts of bottomland forest so that flooding can be controlled (i.e., construction of green-tree reservoirs). In many cases an enhancement for one species or suite of species proves detrimental to many other species. In contrast to enhancement, the process of ecological restoration is holistic and does not favor individual species or particular ecological functions and values to the detriment of other species or functions.

The Need for Restoration

During the last century, a large amount of the original bottomland hardwood forest area in the United States has been lost. Losses have been greatest in the LMAV and East Texas. Of an estimated 9.7 million ha (24 million acres) of bottomland hardwood forest present in the LMAV at the time of European colonization, only 2.1 million ha (5.2 million acres; 22%) remained by 1978 (MacDonald and others, 1979). Approximately 63% of the original bottomland hardwood forest area in East Texas has been lost (Frye, 1987). Proportionally, the most extreme losses of bottomland hardwood forest have occurred in the northern part of the LMAV; in southern Illinois, about 98% of the original bottomland hardwood forest area has been lost (Tiner, 1984).

The primary cause of bottomland hardwood loss has been conversion of the land to agricultural production. Approximately 87% of wetland losses in the United States as a whole has been attributed to agriculture (Tiner, 1984), and the losses of forested wetlands in the LMAV have corresponded very closely to the expansion of agricultural land (MacDonald and others, 1979). Additional losses of bottomland hardwood forests have been caused by construction and operation of flood control structures and reservoirs, drainage and conversion to pine forests, surface mining, petroleum extraction, and urban development.

While many of these alternative uses of bottomland hardwood forest sites are important economically, the functions and values of intact bottomland hardwood forests (storage of floodwaters, water quality improvement, provision of wildlife habitat, etc.) are becoming increasingly appreciated. These functions and values have been described both in technical terms (Wharton and others, 1982; Taylor and others, 1990; Wilkinson and others,

1987) and in terms readily understood by nontechnically oriented readers (Harris and others, 1984).

Growing public concern over the loss of bottomland hardwood forests and wetlands in general has resulted in unprecedented opportunities for protection of this valuable resource. Clearly, preservation of the existing bottomland hardwood resource—through fee title acquisition, easements, or other means—should be the preferred protection strategy. Given the magnitude of the losses that have already occurred, however, restoration of former bottomland hardwood habitats has become a key element in an overall strategy of protection. Over the past 10 years, at least 62,500 ha (154,000 acres) were reforested within the LMAV. Most of this area was planted by the Natural Resources Conservation Service (through the Wetland Reserve Program) or the U.S. Fish and Wildlife Service, although other state and federal agencies have also been involved in planting bottomland hardwood forests (King and Keeland, 1999). The rate of reforestation has been increasing to the point that the amount of LMAV land scheduled for reforestation by all agencies over the next 5 years totals 74,200 ha (183,300 acres). Although the amount of land being restored is commendable, the continuing losses are staggering. From the mid-1970's to the mid-1980's (the most current data available) a total of 364,200 ha (900,000 acres) of forested wetlands were lost in the LMAV region of Arkansas, Louisiana, and Mississippi. Obviously, we are a long way from our national goal of no net loss.

Restoration and Mitigation

The term "mitigation" in this guide refers to the process of rectifying or compensating for the impact on a wetland of a specific development project. In the strict sense, mitigation is a much broader concept than restoration, including avoidance (no impacts to wetlands) and minimization (project modification to reduce the amount of wetlands to be affected) (40 CFR 1508.20 [1998]). Mitigation is usually required as part of the process of obtaining a permit for a development project, such as a "404" permit (Section 404 of the Clean Water Act) for dredge or fill operations in a wetland. Thus, mitigation refers to activities taking place in a regulatory environment. Restoration in this situation can help achieve no net loss of wetlands, but it is not likely to make a significant contribution to making up for past losses.

Because so much of the bottomland hardwood resource has already been lost, the greatest contributions are likely to be made by restoration projects that are not done as mitigation. Voluntary projects to restore agricultural fields, old unreclaimed surface mines, and other such sites on public and private lands are needed if restoration of bottomland hardwood forests is to be achieved on a scale significant enough to achieve a net gain of wetlands.

Restoration, Ecosystems, and Landscape

This guide contains information that is specific to restoration of forested wetlands of the Southeast and lower Midwest. The best approach to restoration is to maintain the overall integrity of ecosystems, including the entire global ecosystem. In practice, however, most restoration projects are conducted in isolation, on a site-specific basis. It is probable that some opportunities to increase the value of an individual restoration project are simply overlooked because not all restorationists are used to thinking of their projects within an ecosystem or landscape context. Therefore, it is worthwhile to consider individual restoration projects within a larger, long-term context.

Where sufficient flexibility exists, restoration sites should be selected to maximize their usefulness within a larger geographic area. One obvious example is to locate the site where it will have the most beneficial impact on water quality (or other desired function) within a watershed. Prime locations are along the edges of existing streams or rivers, especially where the site will act as a buffer between farm fields and other nonpoint sources of pollution and the waterway. Also, by placing a forested wetland near the lower end of a small watershed, it may act as a filter for runoff and floodwaters from the entire area upstream. By shading the water and increasing inputs of plant debris and invertebrates, restoration sites along waterways will also improve habitat values for fish. In some cases, it might be beneficial to choose a restoration site that can act as a screen between an existing site, such as a marsh used by waterfowl, and a road, housing development, or agricultural area.

Opportunities to maximize wildlife habitat values should also be sought. For instance, choosing sites that will increase the size of an existing but isolated tract may improve habitat for forest interior species and reduce nest predation and parasitism. Many of the species in most need of protection require the interior habitat provided by large tracts. On the other hand, sites that will provide a travel corridor between existing tracts of forest might be more valuable than isolated sites in some cases. Corridors, however, may actually have negative or minimal impacts on some wildlife, and any reader contemplating creating a corridor is urged to look at some of the recent literature on this subject (Simberloff and others, 1992; Hobbs, 1992; Rosenberg and others, 1997; Tiebout and Anderson, 1997).

Those involved in land management and restoration should keep abreast of developments in fields such as conservation, biology, and systems and landscape ecology to the greatest extent possible. By developing an increased appreciation of ecosystem and landscape level processes, land-use planners, managers, and restorationists may be able to greatly increase the environmental values of their projects.

The Environmental Impacts of Restoration

The process of restoration can have both positive and negative impacts on the environment. While it is clear that a successfully restored site is healthier and more desirable than a degraded site, there may well be some hidden environmental costs associated with the restoration process that can call the overall value of the project into question.

One of the most obvious negative impacts associated with restoration is when one wetland is degraded to restore another. Plants or topsoil are sometimes removed from intact wetlands and moved to restoration sites. When this causes significant damage to the intact wetland, then the net benefit of the project must be considered to be significantly reduced. Fortunately, this issue is being addressed by professional restorationists, and especially with the ever-increasing availability of commercially produced seed and seedlings, is becoming less of a problem.

The creation of green-tree reservoirs is a common forested wetland management practice that has been shown to degrade bottomland hardwood stands in the Southeast. A green-tree reservoir is typically flooded in the fall to provide waterfowl habitat and then drained during the next spring. This usually changes the timing, duration, extent, and frequency of flooding within these systems. Although flooding during the dormant season is generally not thought to harm most bottomland hardwood tree species, studies have shown that the repeated flooding of green-tree reservoirs can result in the loss of the less water tolerant species. Quite often, the hard mast producing species that the manager wants to maintain, such as Nuttall, cherrybark, and willow oaks, are the very species killed by this management technique. These more desirable species are often replaced by overcup oak, water hickory, swamp red maple, green ash, and baldcypress. In addition, most green-tree reservoirs in the LMAV are not dewatered on schedule each spring (Judy DeLoach, U.S. Army Corps of Engineers Regulatory Functions Branch, Memphis, TN, oral commun.), further impacting the desirable hard mast species.

Another negative impact associated with some projects is the destruction of a healthy upland site to create a wetland. The net benefit of this type of project, which is often required by regulatory agencies, is highly questionable, especially because of the low degree of certainty that a fully functional, sustainable wetland can actually be created on a former upland site. While this kind of project could conceivably have an overall net benefit in some cases, the decision to destroy an upland site to create a wetland should never be taken lightly.

Hydrologic restoration is encouraged to the greatest extent possible; however, full consideration must be given to the landscape context in which the restoration will be developed. Many river processes, such as erosion, sedimentation, etc., are occurring at an accelerated rate. Floodplain wetlands can be overwhelmed and/or severely degraded if unnatural fluctuations in river flow and unnatural loads of sediment, nutrients, and contaminants in the river are not reduced to approximate predisturbance levels (Humburg and others, 1996; Sparks and others, 1998). In this case, the restored vegetation may be destroyed and the site filled in with sediment to the point where it can no longer be considered a (viable) wetland.

Some restoration projects involve extremely high expenditures for the restoration of relatively small areas. It seems reasonable to consider the opportunity costs associated with such projects. For example, is expending $100,000 or more to restore a small, isolated wetland in an industrial area worthwhile, or would it be better to put that money towards some other environmentally oriented project that might have a larger net benefit? There is no simple way to determine the answers to such questions, but they are still worth considering.

Finally, the costs associated with energy-intensive restoration projects should be considered. Use of heavy earthmoving equipment, irrigation, and other operations associated with restoration projects all require energy, primarily from fossil fuels. Even use of nursery-produced planting stock (versus direct seeding or natural regeneration) may involve a moderately high expenditure of energy. Because production and consumption of fossil fuels and most other forms of energy involve negative impacts to the environment, energy efficiency should be considered when planning a restoration project. Although it should certainly not be used as an excuse for skimping on necessary operations such as good site preparation, energy inputs to restoration projects should be reduced where possible.

Sustainability of Restoration Projects

Restored wetlands are no different than other ecological systems in that they are both naturally dynamic and subject to future human-induced perturbations. Examples of natural changes that might be expected to occur include succession and damage caused by storms, animals, insects, or disease. Examples of human-induced perturbations include changes in hydrology as encroaching development increases runoff into the wetland and long-term changes in global climate effects on local weather patterns.

In cases where there is a desire to limit or control natural change (e.g., to maintain a restoration site in a stage dominated by early to midsuccessional species), long-term management of the site needs to be planned. The silvicultural techniques discussed in Chapter 14 will be the primary tools for most forms of long-term management.

The concept of "freeboard" has been suggested as one way of increasing the sustainability of a restoration site in the face of human-induced changes in hydrology (Willard and Hiller, 1990). This concept is that the restoration site should be designed so that there is room for the desired plant community to shift to higher or lower elevations in response to gradual shifts in the site's hydrology. Wetlands with steep transitions to uplands or steep dropoffs to deep water do not have as much freeboard as sites with long, gentle slopes and therefore should be avoided where possible.

The one certainty about a restoration project is that, as time passes, it will be subjected to both natural and man-made agents of change. Restorationists, therefore, need to consider multiple decades when designing projects and not just project time specified in permits or the lifetime of the first generation of trees.

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Chapter 2: General Planning Considerations

A successful restoration project starts with good planning. In general, the plan should define the goals for restoration and subsequent management of the project site and should identify specific procedures to meet the goals. The major steps in the planning process are (1) identify goals; (2) characterize the restoration site; (3) select species to be restored; (4) develop a design for the site; (5) determine site preparation needs; (6) determine best regeneration method(s); (7) determine what postregeneration operations will be carried out; (8) develop a timetable for obtaining planting stock, equipment, and personnel; (9) develop a budget and identify the source of funds; and (10) develop specific performance standards for evaluating project success. Some of these steps are discussed in this chapter while all are covered in more detail throughout the manual.

Project Goals, Objectives, and Success Criteria

Ideally, restorationists should begin their projects by developing a list of general goals or long-term objectives. General goals might include something like (1) establishment of a bottomland forest similar in species composition to the original forest or (2) establishment of a forested wetland that will provide wintering habitat for mallards and wood ducks.

Once general goals have been listed, more specific objectives can be developed. An example of a specific objective is a list of the species to be established and the number of each to be planted per hectare (acre). Another specific objective might be that the site should either flood naturally or have the capability of being flooded artificially during the winter months so that waterfowl can feed within the forest. Much time, effort, and money can be wasted on a project if objectives are not specified in the planning stage, yet simply developing a set of objectives is not sufficient. Specific performance criteria should also be developed to help assess whether the objectives are being met.

Frequently, project objectives are limited to the establishment of vegetation. Success criteria for these projects are often simple, such as the survival rate of all species planted should be at least 50% after one complete growing season, or a minimum of 980 trees per ha (400 per acre) of preferred species should be established on the site; the trees should be at least 2 m (~6 ft) tall and have been growing on the site for at least 24 months.

Therefore, specific goals or objectives and success criteria ideally should be established for all elements of the restoration project. In addition to vegetation, it is desirable to establish criteria for soils, hydrology, water quality, and fish and wildlife habitat. The Mitigation Site Type classification system (MiST; White and others, 1990) provides both general and specific success criteria for bottomland hardwood restoration projects (table 2.1). Although these criteria are directed toward mitigation, they can serve as a starting point for developing more specific success criteria for a given project. The MiST is recommended reading for all restorationists involved with bottomland hardwood and other forested wetland systems. In many ways the planning process from an overall landscape perspective is an artistic process and deserves optimum time and attention to detail before moving forward toward implementation.

Project Site Design

The level of effort put into project site design can vary considerably. For small projects that do not involve extensive earthmoving or are not being carried out for mitigation, the design may simply be what a restorationist envisions. For larger, more complex projects, the process of site design may involve development and review of a series of engineering drawings depicting surface contours, structural specifications, and locations of various forest types to be planted (fig. 2.1). Regardless of the level of detail in the final design, the process of site design should only begin after project objectives have been determined and the site evaluation is completed.

The three-stage design process outlined in the Soil Conservation Service's (now the NRCS) Engineering Field Handbook (Soil Conservation Service, 1992a) is appropriate for the design of restoration projects. Their first step, data collection and evaluation, is analogous to the site evaluation process described in Chapter 3.

The second stage is the development of a preliminary design, which consists of (1) developing a list of the general project features; (2) identifying any structures needed; and (3) developing a preliminary layout of the site (e.g., contours, location of any stream channels, and location/area of vegetation types to be established). The preliminary design may consist of a variety of alternatives and should be sufficiently detailed to allow for a well-informed choice of alternatives based on both ecological and economic grounds.

The third stage is development of the final design, which consists of (1) assessment of the accuracy of the data used in the preliminary design; (2) review of the accuracy of all drawings developed in the preliminary design; (3) selection of alternatives; (4) development of final drawings depicting site layout and any structures; and, ideally, (5) production of a report covering both the

Table 2.1. General definitions of mitigation success used in the Mitigation Site Type classification system (MiST) (see White and others, 1990 for more information).

General definitions of mitigation success
Vegetation
Successfully mitigated project sites shall contain:
(1) An approved species composition represented by self-sustaining species populations.
(2) Adequate tree abundance in terms of overall density and spatial distribution throughout the project site.
(3) Well-established trees (e.g., trees should have been growing on site for at least 1 year).
(4) An adequate representation of undergrowth species.
Soil
A successfully mitigated site will be considered acceptable if it has the physical and chemical properties that are necessary for the successful reestablishment of the desired forest ecosystem. At a minimum, the soil will contain hydric characteristics as listed in the definitions of the current U.S. Army Corps of Engineers Wetland Delineation Manual.
Hydrology
Successfully mitigated sites should have conditions similar to an undisturbed reference ecosystem, particularly in the frequency, duration, and seasonality of the flooding or soil saturation and the source of the water.
Water quality
Water quality success will be achieved when the frequency distribution of monitored parameter values for the project site overlaps 90% of the frequency distribution of the reference site when graphically represented. Minimally, measured levels of parameters should not violate State or Federal water quality standards.
Fish and wildlife habitat
Because of the long-term nature of forested wetland restoration, the habitat for fish and wildlife will be considered restored if the success criteria for vegetation, soils, and hydrology are met.

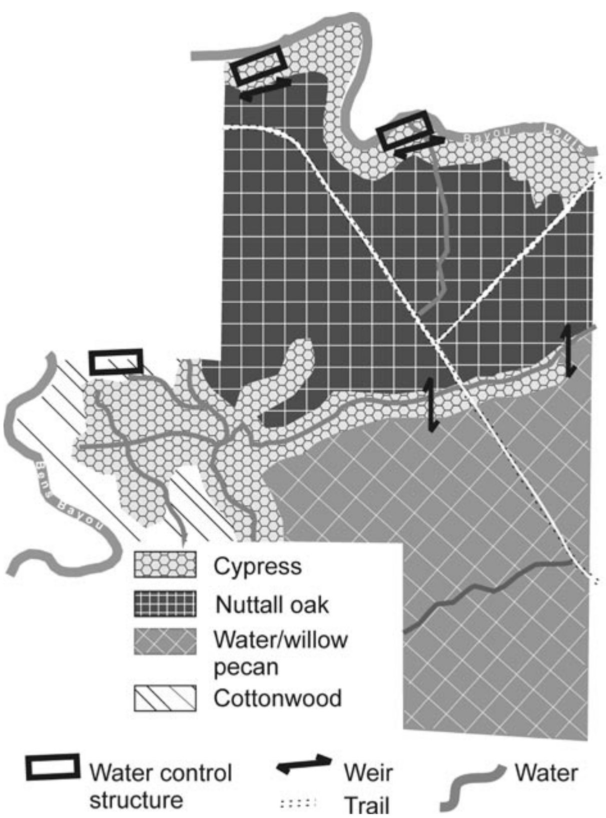

Figure 2.1. Engineering drawings depicting surface contours, structural specifications, and locations of various forest types to be planted can be helpful when designing a restoration project.

final design and a plan for any relevant operation, maintenance, and monitoring.

Review and approval by a licensed civil engineer may be required for designs of structures and surface contours. Local NRCS officials and relevant regulatory agencies should be contacted to determine what regulations apply to restoration project designs.

Regeneration Method

Several regeneration methods have been used effectively to restore bottomland hardwood forests. These methods include direct seeding, planting seedlings, planting cuttings, and transplanting saplings or larger trees. Natural regeneration and topsoiling (the spreading of topsoil from a healthy wetland over a restoration site to introduce seeds and other propagules) are other options that are effective in some cases and should also be considered. Regeneration methods are described in more detail in Chapters 7, 8, 9, and 10.

The final choice of regeneration method should be based on a thorough knowledge of the advantages and disadvantages of each method, characteristics of the species to be planted, condition of the site, availability of planting stock, personnel, equipment requirements, and costs. It is worth noting that, on many restoration projects, combinations of planting methods have been used effectively. For instance, direct seeding might be used as a primary method for regenerating trees, while topsoiling could be employed to introduce understory species, and seedlings of some difficult to establish tree species could be planted.

Decisions about regeneration methods on a given project should be made well in advance of the planting date to ensure the availability of suitable planting stock. If planting is scheduled for late fall through spring, then the choice of planting methods should ideally be made the previous spring or summer for small sites (smaller than about 8 ha [~20 acres]), and even earlier for large sites.

In a survey of federal and state agencies involved in restoring/reforesting bottomland hardwood sites, King and Keeland (1999) found that nearly half of the restorationists experienced problems obtaining sufficient seed of the desired species, and that greater than 80% were unable to obtain the required number of seedlings. In many cases the restorationists were forced to use substitute species. For example, a general shortage of ash seedlings in 1998 forced restorationists to search for seedlings of a variety of other species as replacements.

Obtaining Planting Stock

In most cases, it is best to obtain planting stock from existing suppliers; exceptions will occur most frequently in the cases of large-scale or long-term restoration programs or when using cuttings, transplants from the wild, or direct seeding. A large number of suppliers operate in the region covered by this guide, including state forestry commission nurseries, private nurseries, and both large- and small-scale seed suppliers (see Appendix C for a partial listing of suppliers).

In general, it is best to obtain planting stock as locally as possible. If purchasing planting stock from a local supplier, be sure that their seed was collected from an acceptable (local) source, which will help ensure (but not guarantee) that the stock is adapted to the region where the planting will take place. It may also help reduce damage to planting stock from shipping. Also, nurseries may need lead time greater than 1 year for unusually large orders of seed or seedlings.

Personnel Requirements

Project planning and supervision should be carried out by well-qualified personnel. The project manager should know which specific technical skills are needed to design a project (e.g., forestry, plant ecology, civil engineering, hydrology) and should take the necessary steps to ensure that skilled personnel are available for each task.

It is also important to ensure that personnel who actually implement the project in the field have the requisite skills and are closely supervised. Personnel may be required for skilled (and sometimes dangerous) tasks, such as heavy machinery operation and herbicide application, and for simpler tasks, such as tree planting. The temptation exists to hire an inexpensive, untrained labor force that is poorly supervised, especially for the simpler tasks. The success of some projects has been drastically reduced, however, by the use of poorly trained and inadequately supervised personnel (table 2.2).

Equipment

Some of the equipment needed for restoration projects is described in the following chapters. Actual equipment needs will obviously vary, depending on type of site preparation needed, planting method(s) used, etc. The restorationist should determine in advance what equipment will be needed and take steps to ensure its availability at the appropriate time. Table 2.3 lists some of the equipment that may be required for a restoration project.

Timing of Project Operations

The need to plan in advance for the acquisition of equipment and planting stock has already been mentioned. In addition, careful planning of the overall operations of the project is required.

Forested wetlands typically have periods where the soil is too wet for heavy equipment to operate. Even if the equipment can operate under wet site conditions, this practice should be avoided in order to minimize compaction and soil erosion. Dry seasons, usually in late summer or fall over most of the area covered by this guide, are a good time to do most of the jobs that involve

Table 2.2. Seven "grievous errors" that have been made on restoration projects in the absence of adequate training and supervision (Clewell and Lea, 1990).

1. Vigorous saplings were loaded at a nursery into open trucks and delivered to a project site dead from windburn and desiccation. The unsupervised planting crew planted the dead trees.
2. Potted trees were delivered on a Friday afternoon and allowed to roast in the direct summer sun before being planted dead on Monday.
3. Gallon-sized trees were removed from flat-bottomed pots and planted in holes dug with pointed spades. Air pockets remained beneath their root balls and stressed or killed many saplings.
4. Nurseries shipped trees of the wrong species, the error was either unnoticed or unreported, and the trees were planted.
5. Mesic trees were planted in hydric sites.
6. Cuttings of willows and cottonwoods were planted upside down.
7. Project sites were not fenced or staked, and work crews planted up to 40% of their seedlings on adjacent land.

Table 2.3. Partial list of equipment occasionally used in restoration projects and examples of how they are used.

Equipment	Use(s)
Dragline	Excavation; removal of topsoil
Scraper	Removal, segregation, and transport of soil and/or overburden
Bulldozer	Removal and spreading of soil and/or overburden; surface contouring
Dump truck	Transport of topsoil
Front-end loader	Removal of soil and/or overburden; loading trucks
Tractor	Site preparation; planting; weed control; fire lane construction
Rippers, chisel, plows, offset disks	Reduction of soil compaction; preparation of soil surface for planting
Mechanical seed planter	Direct seeding
Mechanical seedling planter	Planting bare-root seedlings
Gasoline-powered soil auger	Planting containerized seedlings
Tree spade	Transplanting saplings and larger trees
Dibble bar, sharpshooter shovel	Hand planting seedlings
Backpack sprayer	Weed and exotic plant control
Brushhook, machete	Vine control

earthmoving or other site preparation jobs requiring heavy equipment.

In some cases, sufficient time must be allowed between site preparation and planting so that the soil can settle, the hydrology can be double-checked, a green manure crop can be planted and plowed under, and so on. For relatively complex restoration projects, a schedule of operations should be prepared and approved by key personnel involved in project planning and implementation.

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Chapter 3: Evaluation of the Site

Site is a central concept in the practice of forestry and forest restoration. The term "site" is rarely defined precisely but may be interpreted as being synonymous with the term "habitat." It refers to the place in which trees grow and encompasses both the abiotic (nonliving) and biotic (living) factors that may have an impact on the survival and growth of the trees. The size of an area that is considered one site can vary considerably, as long as the critical environmental factors remain relatively the same.

The term "project site" is used occasionally in this guide. In some cases the project site may be homogeneous enough to be considered as one site in the ecological sense of the word. In other cases, variation within the project site, such as different degrees of flooding, different soil types, slope, aspect, existing vegetation, etc., may require that it be treated as a number of smaller sites, each of which may have different site preparation needs, specific levels of suitability for different species, and so on.

In this chapter, it is assumed that the site to be restored has already been chosen. It is expected that the choice of sites will be limited in most cases, either for legal reasons (e.g., permit requirements that a specific area be restored after surface mining) or for management-related objectives (e.g., the desire to provide a travel corridor for wildlife between two large blocks of forest). The principles described in this chapter, however, can also be used to select a site for restoration.

Once the site is identified, the first task is to conduct a site evaluation. Site evaluation can be informal, involving no more than a windshield survey, or it can be much more elaborate (and expensive), involving the development of ecological baseline information by means of prerestoration monitoring (e.g., hydrology) and analytical testing (e.g., soil characteristics). The intensity of the evaluation will depend on factors such as the restorationist's prior experience with similar sites, the degree to which the site has been altered, and available funds. At a minimum, the site should be walked over or traveled by ATV to confirm the restorationist's expectations from various sources (e.g., NRCS soil survey, etc.). Whatever the intensity of the evaluation, the abiotic and biotic factors described in this chapter should be considered.

Abiotic Site Factors

The most important abiotic factors to be considered in bottomland areas are climate, hydrology, and soils. These three factors interact with each other but are treated separately in this section.

Climate

Climate is one of the major factors affecting tree species distribution and the growth of individual trees. The primary climatic factors operating on trees are precipitation (amount and distribution), temperature regime, and evapotranspiration.

Although climate is critical, it is generally not the most important aspect of a site evaluation as long as the species to be established are within their natural range. There is little or no practical need for a detailed climatic assessment if the planting stock is known to be well adapted to the area. Knowledge of the normal variation in local climate could be very important, however, as the success of any plantings could be adversely affected by extremes of temperature and/or precipitation (i.e., drought or flooding) during the first year or two after planting.

The consideration of climate becomes most important when the introduction of a species not indigenous to the area—or a different subspecies or provenance of an indigenous species—is contemplated. In such cases, it is important to know the general climatic characteristics of the site (see table 3.1), but it may be even more important to know the climatic extremes that can occur. Forestry literature is replete with examples of species introductions that were successful until some natural but uncommon event occurred, such as a prolonged drought or flood, an unusually long, deep freeze, or an ice storm. By definition, nonnative species should not be used in restoration projects.

Table 3.1. Abiotic site data that should be obtained if possible.[1]

Climate	Hydrology	Soils
Mean annual rainfall	Mean annual flood duration	Degree of soil saturation
Mean monthly rainfall	Mean growing season flood duration	Presence of pans or depressions
Mean monthly temperature	Mean growing season water table depth	Degree of mottling
Evapotranspiration potential	Hydrologic system	Percent organic matter
Incidence of droughts, extreme cold, extreme heat, ice storms, and hurricanes	Topographic position	Soil type, texture, structure, depth, pH, compaction, and color

[1] Where mean data is specified above, it is also desirable to obtain an indication of variability (e.g., standard deviations).

Occasionally, microclimate can be an important consideration, but this is less often the case on bottomland sites than on upland sites, where slope and aspect may greatly affect the temperature and moisture regime. The exposed nature of most restoration sites, which can result in hotter and drier conditions than in adjacent mature forested wetlands, must be considered. Frost pockets—low, concave areas that tend to trap cold air—are also sometimes a problem within restoration sites at relatively high elevations. Such areas are not likely to occur on large floodplains, but where present, frost pockets may result in direct damage to trees or may literally uproot seedlings by the process of frost heaving.

Hydrology

Hydrology is the most important factor affecting the local distribution of bottomland tree species within their natural ranges. Hydrology as treated in this guide refers to the frequency, duration, depth, seasonality, and source of flooding and/or soil saturation that occur on a site, as well as the depth of the water table.

Detailed hydrologic data, such as the first three items listed in table 3.1, will often not be available for a given site but should be obtained to the greatest extent possible. The U.S. Geological Survey's Water Resources Division provides real-time hydrologic data online at http://water.usgs.gov. In most cases, the restorationist will have to make do with knowing only the hydrologic system type and the topographic position of the site. Fortunately, much can be inferred about a site's hydrologic characteristics from this information.

The main hydrologic systems in the the lower Midwest and southeastern United States are large alluvial rivers, minor stream bottoms, blackwater rivers (those originating in the Coastal Plain), spring-fed streams, isolated basins, backwater swamps, bogs, and seep areas. Different hydrologic systems can have very different flooding patterns (fig. 3.1). Large alluvial rivers tend to have longer periods of high water, with most of the flooding occurring between November and May. Minor stream bottoms and blackwater rivers tend to have more erratic flooding, since these smaller systems are more responsive to local precipitation. Spring-fed streams, bogs, and seeps tend to have much more stable hydrologic patterns, and groundwater table levels assume greater importance than overbank flooding.

Topographic positions within floodplains include sloughs, natural levees, lower floodplain or first bottoms, terraces, and slopes (transitional areas to uplands; fig. 3.2). The depth and seasonality of flooding, as well as numerous other site characteristics, varies substantially with topographic position. Other sites such as cypress domes support forested wetlands somewhat similar in nature to bottomland hardwoods. These wetlands typically occur as isolated basins rather than within a riverine floodplain.

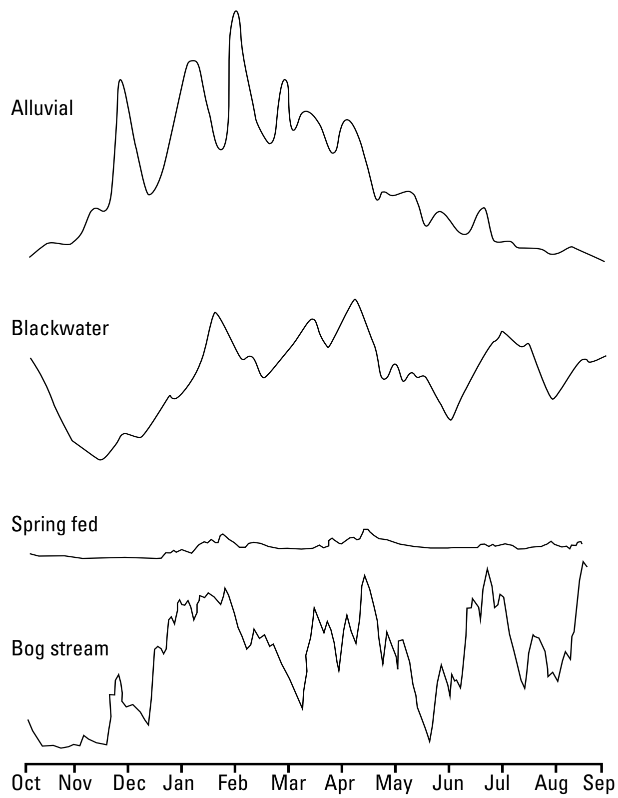

Figure 3.1. Hydrographs of typical bottomland hardwood sites (redrawn from Wharton and others, 1982).

It is important to realize that hydrologic alterations have occurred at most sites. Drainage and flood control projects, diversions of flows, pumping from aquifers, road construction, and numerous other developments are so ubiquitous that nearly every site has a hydrologic regime different than it had 50-100 years ago. A tract of mature forest in the immediate vicinity can be very informative. If the existing overstory trees in the tract look stressed, or the understory trees are mostly either less or more flood tolerant than the overstory trees, then there may have been substantial hydrologic modifications to the site. Hydrologic records, maps, aerial photos, and interviews with people knowledgeable about the site may all be used to determine what types of hydrologic changes have taken place. It may be impossible to restore a site's hydrology back to historic conditions.

In cases where the natural hydrologic pattern of a site has been altered drastically, or for areas that are not naturally bottomland hardwood sites, more specific hydrologic information may be necessary. Along

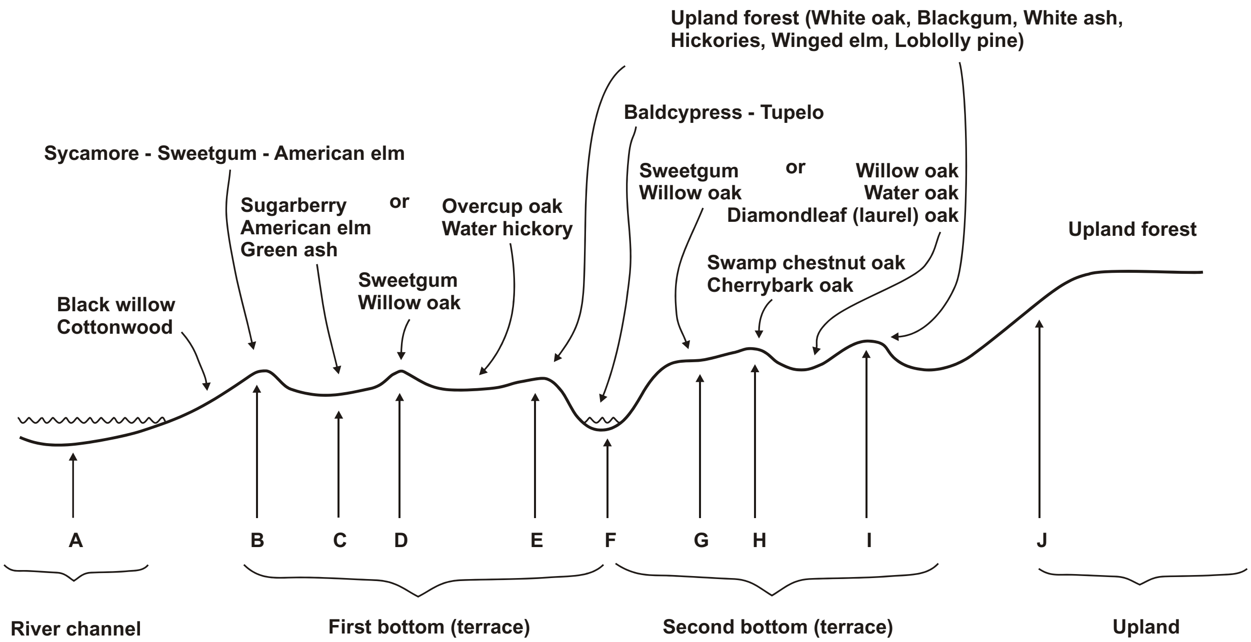

Figure 3.2. Topographic positions and associated forest cover types within a river floodplain (modified from Wharton and others, 1982).

reservoir shorelines, for example, water levels may fluctuate dramatically, and seasonal patterns of flooding and drawdown need to be understood in detail. In areas where heavy machinery has been operated, topsoil has been displaced, or water control structures have been installed, surface flooding and/or water table levels may vary considerably from an undisturbed site. On the most heavily disturbed sites, such as surface-mined areas that have been regraded, it is advisable to collect as much detailed information as is available or even to monitor the hydrologic regime of the site prior to selecting species and initiating planting (see Chapter 13).

Soils

Alluvial bottomland soils generally have more clay and organic matter than upland soils, and therefore they tend to have higher moisture-holding capacity, fertility, and productivity. There are numerous exceptions and potential soil-related problems, however, and an appreciation of soil conditions is important for ensuring the success of a restoration project.

A good place to start evaluating the soils on a site is with the county or parish soil survey. Even if the site has been drastically altered, county or parish soil surveys can provide information on the soil originally found on the site. Soil surveys should be used with caution, however, since the information on forested wetland sites is usually much less detailed than information on adjacent agricultural lands. In many instances, the mapped soil type within a wetland may include one to several areas of a different soil type. Soil surveys are available for most of the counties and parishes covered by this guide and can be obtained from local NRCS offices (also see NRCS National Soil Survey Center data at http://www.statlab.iastate.edu/soils/nssc). The restorationist should know what soil series are present on the project site and be familiar with their basic characteristics. A list of some of the soil characteristics that are often important to know and which are for the most part available in soil surveys is provided in table 3.1.

Soil texture (relative amounts of sand, silt, and clay) is basic information for a restorationist because texture affects other soil characteristics important for tree survival and growth and also because it may greatly affect planting operations. In particular, heavy clay (and organic soils) can present difficulties for planting operations.

Soil moisture characteristics are also critical (see hydrology section, this chapter). In addition to the hydrology data listed in table 3.1, soil color and mottling can provide good indications of the degree of soil saturation. Dark, dull soils (i.e., those with low chroma values) indicate prolonged soil saturation. Soils that are somewhat less saturated may contain brightly colored mottles.

Although soil surveys can provide much information, they are not a substitute for an on-site examination or for soil testing, especially if the site has been heavily disturbed. If there is evidence of soil compaction (e.g., signs of overgrazing, ruts caused by heavy machinery, lots of puddles), it would be worthwhile to determine the bulk density of the soil. Most bottomland hardwood trees will not grow well if bulk density exceeds 1.4 g/cm^3, and they may not survive if the bulk density exceeds 1.7 g/cm^3. Soil penetrometers (fig. 3.3), or simple soil probes, can be used as a quick means to assess the degree of compaction.

On some sites, in particular areas that have been surface-mined for coal, soil pH assumes great importance. Soil pH on these sites may be below 4.0 to 4.5, which is the lower limit that most bottomland species apparently tolerate. Soil can also be too alkaline. Some riverfront soils along the Mississippi and Red Rivers have pH values of 7.5-8, and this degree of alkalinity has probably been responsible for the failure of planting trials with oak species such as Nuttall and cherrybark. Sites mined for phosphate may also have a pH in excess of 7, which is high enough to affect the survival and growth of some bottomland hardwood species.

Figure 3.3. Soil penetrometer being used to assess soil compaction.

Nutrient deficiencies are generally not a problem on bottomland sites, except where soils have been drastically disturbed (e.g., by surface mining or topsoil removal) or have been in agricultural production over long time periods. In such cases, nitrogen is likely to be deficient. Nutrient deficiencies may be detected by soil tests. Guidelines for soil sampling, testing, analysis, and interpretation can be found in some of the references at the end of this chapter.

Biotic Site Factors

Four biotic factors may affect the success of a restoration project: plant competition (including competition from exotic species), animals, insects, and disease.

Plant Competition and Exotic Species

Competition from other plants for light, water, or nutrients may reduce the survival and growth of planted trees. Although there have been cases where the partial shade caused by competing vegetation actually increased survival of planted trees—and planted trees will usually win out over weeds given enough time—competition generally reduces both overall survival and initial growth. In addition, a heavy plant cover can (1) interfere with tree planting operations, (2) provide habitat for small rodents and other animals that can consume planted seeds or seedlings, and (3) serve as fuel for wildfire. It is therefore important to evaluate the current plant cover on the restoration site and also attempt to determine what type of plant competition may occur after planting.

Certain types of plants can be particularly harmful to planted trees. A heavy growth of vines, for example, can shade tree seedlings and their weight can cause bending or physical damage. Some exotic weeds, such as Johnson grass, Vasey grass, and cogongrass grow so tall and thick that they can reduce growth and significantly increase mortality of planted trees. Fescue, bahia grass, and other turf-forming grasses that are commonly planted for pasturage and erosion control often compete successfully against young planted trees for water during times of drought.

The amount and type of weeds that can be tolerated on a site before or after planting depends on the objectives of the project and the planting methods being considered. There is rarely a need to quantify the weed cover precisely, but it is useful to know if weeds cover much of the site, how tall the weedy vegetation is, and what dominant species are present.

An attempt should be made to determine in advance what type of plant competition may arise after planting. This determination will aid in the planning and budgeting of postplanting operations and can be accomplished by examining similar restoration sites, reviewing available literature, the NRCS Plants Database (http://plants.usda.gov/), or talking to people with knowledge of the area (such as county foresters or agricultural extension agents).

In many restoration projects done as mitigation, there is a requirement that no more than a certain percentage of the total plant cover (typically 5-10%) consists of exotic species. Therefore, a special effort needs to be made to determine in advance what types of exotic plants are likely to become established and what control measures will be necessary. Exotic species of particular concern include melaleuca, Brazilian pepper, and cogongrass in peninsular Florida. Elsewhere, nuisance exotic species may include Chinese tallow, Japanese honeysuckle, kudzu, multiflora rose, wild grapes, and various turf grasses.

Animals

Both domestic animals and various wildlife species may damage or destroy planted trees. The animals most likely to cause damage to planted seeds or seedlings include deer, raccoons, beaver, nutria, small rodents, cattle, and hogs. The restorationist should therefore find out if any of these animals are present in numbers large enough to affect tree species selection or to make specialized protection measures necessary. An accurate appraisal of deer damage may best be obtained by requesting the assistance of a wildlife biologist from the state wildlife agency.

Field personnel need to be trained to look for and recognize animal damage in potential restoration sites (Larry Savage, Louisiana Department of Wildlife and Fisheries, oral commun.; Waller and Alverson, 1997) because grazing can affect the long-term species composition of the site. In the bottomland hardwoods of southern Illinois, deer browsing on planted oaks and natural sugarberry have resulted in an overabundant advanced regeneration of the less palatable sweetgum and boxelder (Larry Savage, Louisiana Department of Wildlife and Fisheries, oral commun.). Boerner and Brinkman (1996, p. 309) reported that “deer browsing was more important than environmental gradients or climate factors in determining seedling longevity and mortality.” Seedlings that are fertilized and irrigated in nurseries are especially preferred by browsing deer.

Rodents have caused extensive mortality to restoration projects that have used direct seeding. Savage and others (1996) reported successful seedling establishment by seeding willow oak acorns at rates 62% higher than normal (5,982 per ha [2,420 per acre]) in spite of extensive damage caused by rice and cotton rats. In areas subject to long-term flooding, nutria and beaver have been especially damaging. Nutria can decimate baldcypress regeneration and are a major factor limiting baldcypress regeneration in swamp forests of Louisiana (Conner and others, 1986). Damage to baldcypress usually consists of pulling up the seedling and eating the bark from the taproot. Although seedling protectors have proven successful in some studies, they have not been universally successful and add substantially to the cost of planting.

Insects and Disease

Numerous injurious insects and diseases affect bottomland hardwood tree species. Many of these agents can drastically lower the value of trees for timber production, but seldom will they cause the total failure of a restoration project. Most cases where insects or disease destroyed large numbers of planted seeds or seedlings occurred when the trees planted were not well suited to the site and were therefore heavily stressed. Although it will generally not be a problem, the potential for insect or disease outbreaks should be investigated any time the restorationist is working in an unfamiliar area.

Human Influences

In addition to abiotic and biotic factors, restorationists should assess the potential for human impacts on the restoration site. Among other things, people may use the site as a play area, drive over it in off-road recreational vehicles or farm machinery, accidentally douse it with herbicides from nearby farm or forestry operations, burn it with a carelessly thrown cigarette, or intentionally vandalize it.

Some indirect human influences are much less obvious but can still cause the total failure of a restoration project. For example, residual herbicides applied to previous agricultural crops can stunt or kill many tree species. Some tree planting failures in the Lower Mississippi Alluvial Valley have repeatedly occurred on fields where milo was grown the previous year, and the effect of residual herbicides was a prime suspect. Although the effect of residual herbicides has not been demonstrated experimentally, it cannot be ruled out as a possible influence on restoration success.

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Chapter 4: Species Selection

Tree species selection is one of the more critical phases of a restoration project. An inappropriate choice can result in a total planting failure, an inadequately stocked and underproductive forest, or a forest of minimal value for wildlife.

The choice of species to be planted depends on the project goals, the characteristics of the site, and the availability of planting stock, equipment, and personnel. An informed choice also requires knowledge of the silvical characteristics (see Burns and Honkala, 1990a,b, "Silvics of North America, Volumes 1 and 2") and uses of bottomland hardwood tree species (Putnam and others, 1960).

There is no standard or widely recommended procedure for selecting the species to be planted. Assuming the goal of the project is full restoration and the site has not been irreversibly modified, information about the original forest composition of the site, or of a nearby forest with similar site characteristics (see reference sites section, this chapter), should be used as the basis from which to begin the selection process. Once the restorationist has an idea of the original forest composition (keeping in mind that forest composition is continually changing), then he or she can begin to narrow the number of species to be planted. Species selected must be tolerant of the soils and hydrological conditions on the project site. Flood tolerant tree species (e.g., Nuttall oak or green ash) can be planted in areas that rarely flood, but less flood tolerant species cannot survive in flood prone areas.

Tree species that are likely to colonize the restoration project site by natural dissemination of seeds or other propagules need not be planted, or at least not in great numbers. Assuming a nearby seed source exists, such species generally include sweetgum, sycamore, and the common species of maple, elm, and ash. These species fruit prolifically almost every year and produce fruits that are carried great distances from parent trees by the wind. In contrast, heavy fruited species such as most oaks and hickories should be planted. Such species may produce mast prolifically only once in several years, and their dispersal mechanisms are weak or unreliable.

If the primary purpose of the restoration is for wildlife habitat, fast growing species such as cottonwood or sycamore can be planted to provide some vertical structure within a few years. These species can attain heights of 10 m or more within 3 to 4 years and could provide Neotropical migratory bird habitat during the early developmental stage of the restoration. As these fast growing trees begin to provide vertical structure, their use by birds will assist in increasing biodiversity through the introduction of numerous seeds (Twedt and Portwood, 1997). An additional consideration, especially on private land, might be the market value of cottonwood or sycamore for pulp within 10 years. Schweitzer and others (1999) reported on an experimental cottonwood plantation that was used to provide a financial return to the landowner within 10 years while acting as a nurse crop to Nuttall oak seedlings. Such innovative plantings can provide multiple benefits, including the development of improved soil structure and increased organic matter, while the long-term target vegetation (the underplanted seedlings such as oak) are developing. Upon harvest, some of the cottonwood trees can be retained to provide future sawlogs or den trees.

To assist with the process of species selection, several types of information are provided here. Selected silvical characteristics and wildlife-related uses of 69 bottomland hardwood species are listed in table 4.1. Supplemental information on species associations and ecological relationships, based on the Society of American Foresters cover types listed in table 1.1, is provided in Appendix A. Additional information on matching species and soil types in the Midsouth is supplied in Appendix D, and for the Southern Atlantic Coastal Plain, information is in Appendix E. Also, several references to more detailed treatments of individual species or other aspects of species selection are provided at the end of this chapter (page 34).

Reference Sites

The concept of a "reference wetland" has been used for several years by professionals involved in wetland restoration and creation for mitigation purposes. Using the reference wetland approach, data are collected on the plant community, hydrology, and other characteristics of a natural, relatively undisturbed wetland on a site similar to and in the vicinity of the proposed mitigation site. These data are then used as a basis for designing the mitigation project and judging its success.

Because of the high degree of variability within natural bottomland hardwood forests, the use of a "reference forest ecosystem" has been proposed. A reference forest ecosystem has been defined as a conceptual forest selected for creation or restoration. It is based on forested wetlands represented locally (in the same or a nearby watershed) in terms of species composition and physiognomy. The key difference between a reference forest ecosystem and a reference wetland is that a reference wetland is a specific wetland, whereas a reference forest ecosystem is a composite description from several similar forested wetlands.

Table 4.1. Characteristics of selected tree and shrub species suitable for reforestation in bottomland hardwood forests of the southeastern United States: typical habitat; flood and shade tolerance; seed ripening and storage requirements; reproductive characteristics; and suitability for direct seeding, wildlife food and habitat, and wood products.

Key to Flood Tolerance:
T (tolerant) —Species are able to survive and grow on sites where soil is saturated or flooded for long periods during the growing season. Species have special adaptations for flood tolerance.
MT (moderately tolerant) —Species are able to survive saturated or flooded soils for several months during the growing season, but mortality is high if flooding persists or reoccurs for several consecutive years. These species may develop some adaptations for flood tolerance.
WT (weakly tolerant) —Species are able to survive saturated or flooded soils for relatively short periods of a few days to a few weeks during the growing season; mortality is high if flooding persists longer. Species do not appear to have special adaptations for flood tolerance.
I (intolerant) —Species are not able to survive even short periods of soil saturation or flooding during the growing season. Species do not show special adaptations for flood tolerance.

Species Name	Habitat	Tolerance		Seed	Seed storage requirements[1]
		Flood	Shade	ripening	
Ash, green *Fraxinus pennsylvanica*	First bottoms and newly deposited sediments except in deep swamps. Most common on flats or shallow sloughs.	MT	Adult = I; Seedling = MT to T	Sept.- Oct.	Sealed container at 41°F (5°C) and 7-10% seed moisture.
Ash, pumpkin *Fraxinus profunda*	Widely distributed on new sediments, in first bottoms, and edges of swamps. Similar to green ash.	T	Adult = I to MT; Seedling = MT	Oct. - Dec.	Sealed container at 41°F (5°C) and 7-10% seed moisture.
Ash, white *Fraxinus americana*	Widely distributed; however, limited to ridges and high hummocky flats of older alluvium, outwashes from uplands, and creek bottoms.	WT	Adult = I; Seedling = MT	Sept. - Dec.	Sealed container at 41°F (5°C) and 7-10% seed moisture.
Bay, loblolly *Gordonia lasianthus*	Swamps, bays, and wet sites in pine barrens of Coastal Plain.	MT	T to I	Sept. - Dec.	Unknown.
Bay, red *Persea borbonia*	Borders of swamps in rich, moist, mucky soil and wet pine and hardwood flats and bays. Not on alluvial sites.	MT	T	Sept. - Oct.	Unknown.
Bay, swamp *Persea palustris*	Pine barrens, swamp margins, and river bottoms.	MT	T	Unknown	Unknown.
Bay, sweet *Magnolia virginiana*	Edges of headwater and muck swamps and pocosins.	MT	MT	July - Oct.	Store in sealed container at 32-41°F (0-5°C). Seeds stored at higher temperatures should not be cleaned.
Beech, American *Fagus grandifolia*	Mostly creek bottoms and occasionally in minor river bottoms and on ridges of old alluvium or terraces.	I	VT	Sept. - Nov.	Store loosely in sealed polyethlyene bags from fall until February of the following winter at 20-30% moisture and 33-41 °F (1-5 °C).

Key to Shade Tolerance:
In some cases a range of tolerance is given depending on the source of the information. Shade tolerance information has been taken from a variety of sources but predominately from Putnam and others, 1960 and Burns and Honkala, 1990.
Adult —Refers to the shade tolerance of adult individuals. This information is given when it is known that adult and seedlings respond differently to shade.
Seedling —Refers to the shade tolerance of seedlings.
VT (very tolerant) —Species are able to survive and thrive in the deep shade of a closed canopy forest.
T (tolerant) —Species are able to survive and grow in shade, but growth and productivity rates may be slowed somewhat if shade is deep.
MT (moderately tolerant) —Species will survive in moderate shade, but growth rates and seed production may be reduced if shading continues over a period of many years.
WT (weakly tolerant) —Species will grow with partial shading for a portion of each day but require some direct sunlight for normal growth. These species will survive codominant but not overtopping competition.
I (Intolerant) —Species require open conditions and full sunlight for normal growth and development.
Key to Suitability:
H = high
M = medium
L = low
I = insufficient data to determine suitability or unsuitability

Reproductive characteristics	Direct seeding	Waterfowl food	Deer/turkey food	Neotropical migrant	Wood products
Germination best on bare, moist soil in openings. Excellent natural seed dispersal. Sprouts well.	I	L	L	I	M
Seedlings establish on bare, moist soil after water has drained off. Sprouts well from stumps.	I	L	L	I	M
Seedlings establish best in openings on bare, moist soil after water has drained off. Sprouts prolifically from stumps.	I	L	L	I	H
Seedlings establish best in relatively open areas with exposed soil.	I	L	L	I	I
Seedlings establish in both understory and openings. Fire stimulates germination. Sprouts well from stumps.	I	L	L	I	L
Seedlings establish both in understory and openings. Sprouts well from stumps.	I	I	I	I	L
Seedlings establish both in shade and especially in openings and heavy thinnings.	I	L	L	I	L
Regeneration is generally sparse but persistent. Seedlings establish best in shade on moist, well-drained soil. Sprouts well from roots and stumps.	I	L	M	I	L-M

Species Name	Habitat	Tolerance Flood	Tolerance Shade	Seed ripening	Seed storage requirements[1]
Birch, river *Betula nigra*	Near river fronts and banks of minor streams. Not below Memphis in the Delta but extends to the coast on secondary streams.	MT	I	May - June	Store at 1-3% moisture content and 36-38 °F (2-3 °C).
Blackgum *Nyssa sylvatica*	Throughout bottoms on ridges and high flats of older silty alluvium. Well drained, silty and loamy soils.	WT	I to WT	Sept. - Oct.	Store over winter in cold, moist sand or in cold storage.
Boxelder *Acer negundo*	Scattered throughout riverfronts of major streams, bottomlands, ridges, and high flats.	MT	MT to T	Aug. - Oct.	Air dry to a moisture content of about 10-15% before storage.
Buttonbush *Cephalanthus occidentalis*	Mostly in Gulf of Mexico coastal plains and Delta. Also in swamps along streams and margins of ponds.	T	T	Sept. - Oct.	Unknown.
Cherry, black *Prunus serotina*	Sparsely scattered through-out on oldest alluvium and outwash from uplands. Often in hammocks.	I	I to MT	Late Aug.-Sept.	Unknown.
Cottonwood, eastern *Populus deltoides*	Mostly on newly deposited soil along major streams, recently abandoned fields, right-of-ways, clean burns, wet spots in pastures, and banks of small drainages and ditches.	WT - MT	VI	May - Aug.	Air dry 4 days at room temperature. Store in stopper vials at 36-40°F (2-4 °C).
Cottonwood, swamp *Populus heterophylla*	Scattered in shallow swamps, in deep sloughs, along often flooded creek bottoms, and on wet spots on low hammocks on the east coast.	MT	I to WT	Apr. - July	Cold storage of 41°F (5 °C) and 5-8% moisture content.
Cypress, bald (baldcypress) *Taxodium distichum*	Very poorly drained organic or clay soils. Swamps, deep sloughs, borders of old lake beds, very wet areas with up to 3 m (10 ft) of flooding. Commonly originates as dense, even-aged stands.	VT	I to WT	Oct. - Dec.	Seeds keep well in dry storage of 41 °F (5 °C) for at least one winter.
Cypress, pond (pondcypress) *Taxodium distichum* var. *nutans*	Shallow piney woods, headwater and/or back swamps, perched ponds, sloughs, and wet flats on lower Coastal Plain, mostly east of the Mississippi River.	T	I	Oct. - Dec.	Seeds keep well in dry storage of 41 °F (5 °C) for at least one winter.
Dogwood, flowering *Cornus florida*	Common in bottoms of minor streams and on well-drained sites.	I	VT	Sept. - Oct.	Store cleaned seeds in sealed containers at 38- 41 °F (3-5 °C) for 2-4 years.

Reproductive characteristics	Direct seeding	Waterfowl food	Deer/turkey food	Neotropical migrant	Wood products
Seedlings establish on moist, well-drained soils. Rapid early growth from seed.	I	L	L	I	L
Sparse regeneration. Germination and establishment only on dry soil. Stumps to 30 cm (12 inches) sprout well.	I	M	M	I	L
Germinates best on moist, bare, mineral soil in shade or openings. Sprouts well from stumps.	I	L	H	I	L
Very moist seed bed is optimum. Stumps of all sizes sprout.	I	M	L	I	L
Seeds establish in bare mineral soil or in leaf litter. Sprouts from stumps.	I	L	M	I	H
Germination best on wet mineral soil. Continued moisture and top light imperative. Sprouts well from stumps up to 30 cm (12 inches).	I	L	M	I	H
Reproduction is erratic and sparse. Germination best on bare, moist, mineral soil. Rapid early growth. Sprouts from stumps up to 30 cm (12 inches).	I	L	M	I	L
Generally poor regeneration but occasionally excellent in openings. Best germination on very moist muck substrate. Sprouting inconsistent from stumps up to 50 cm (20 inches).	I	L	L	I	H
Similar to baldcypress.	I	L	L	I	M
Germination best on bare mineral soil in understory or openings. Stumps of all sizes sprout well.	I	L	H	H	L

Species Name	Habitat	Tolerance Flood	Tolerance Shade	Seed ripening	Seed storage requirements[1]
Dogwood, rough-leafed *Cornus drummondii*	Dry to very wet sites and on soils that range from sand to clay.	T	T	Aug. - Oct.	Store cleaned seeds in sealed containers at 38- 41 °F (3-5 °C) for 2-4 years.
Elm, American *Ulmus americana*	Common on flats in newer alluvium.	MT	MT to T	Late Feb. - June	Store at 3-4% moisture content in sealed containers at 25°F (-4 °C).
Elm, cedar *Ulmus crassifolia*	High flats, poorly drained ridges, usually on impervious silty clay soils.	MT	MT to T	Sept. - Oct.	Air dry and store at 39 °F (4 °C) in sealed containers.
Elm, slippery *Ulmus rubra*	Occasionally on banks of secondary streams.	I	T	Apr. - June	Sealed containers.
Elm, water *Planera aquatica*	Swamps, deep sloughs or low, poorly drained flats. Usually found on clay soils covered with water for part of the year.	T	T	Early spring	Unknown.
Elm, winged *Ulmus alata*	Ridges and high flats of older alluvial soils and terraces. Generally in creek bottoms and hammocks.	WT - I	T	April	Air dry and store at 39°F (4 °C) in sealed containers.
Hackberry *Celtis occidentalis*	Common on flats and river fronts of new alluvium but not in deep swamps.	MT	MT to VT	Sept. - Oct.	Store in sealed container at 41°F (5 °C) for up to 5 ½ years without losing viability.
Hawthorn *Crataegus* spp.	Dry, sandy, stony ridges to moist river bottoms and in margins of swamps.	MT	I	July - Nov.	Unknown.
Hickory, shagbark *Carya ovata*	Moderately well-drained loams.	WT	MT	Sept. - Oct.	Same as for water hickory.
Hickory, shellbark *Carya laciniosa*	On river terraces and on loamy flats in second bottoms. Also grows well on clay and silt loams, dry and sandy soils.	WT	VT	Sept. - Nov.	Same as for water hickory.
Hickory, water (bitter pecan) *Carya aquatica*	Common to flats, sloughs, and margins of swamps of major alluvial streams. Poorly to moderately well-drained clays and loams.	MT	MT	Sept. - Nov.	Store at 41 °F (5 °C) in closed containers for 3 to 5 years. Storage for one winter is achieved by stratification.
Pecan, sweet *Carya illinoinensis*	Current or recent river fronts on moderately well-drained loams.	WT	I to MT	Sept. - Oct.	Store at 41 °F (5 °C) in closed containers for 3 to 5 years. Storage for one winter is achieved by stratification.

Reproductive characteristics	Direct seeding	Waterfowl food	Deer/turkey food	Neotropical migrant	Wood products
Seedlings establish best on moist soil under partial shade. Sprouts well from stumps.	I	L	H	H	L
Germination and establishment on surface of moist mineral soil or on undisturbed humus; seldom on bare areas. Stumps up to 33 cm (13 inches) sprout well. Seeds remain viable submerged for a month.	I	M	M	M	L-M
Seedlings establish in shade or in openings on moist, bare mineral soil. Stumps up to 30 cm (12 inches) sprout well.	I	M	M	M	L
Seedlings establish in shade or in openings on moist, usually well-drained soil. Stumps up to 30 cm (12 inches) sprout well.	I	M	M	M	L
Seedlings establish after water recedes. Sprouts well from stumps.	I	M	L	M	L
Seedling establishment prolific in new openings but sparse in understory. Stumps up to 30 cm (12 inches) sprout well.	I	M	M	M	L
Seedlings often become established in full shade but cannot withstand submergence. Sprouts well from stumps up to 30 cm (12 inches).	I	L	L-M	H	M
Does not readily establish seedlings. Trees are good sprouters.	I	L	M-H	M-H	I
Seedlings require moderately moist seedbed. Sprouts well from stumps.	L	I	M	I	L
Needs moist soil for germination and establishment in understory and openings. Sprouts well from stumps.	I	L	M	I	L
Prolific regeneration in full sunlight. Seedlings are more common in new openings but also occur in understory. Sprouts well from stumps to 50 cm (20 inches).	L	L-M	L	I	L
Adequate regeneration in small or partial openings. Seedlings establish best under about an inch of loamy soil.	M	H	H	I	H

Species Name	Habitat	Tolerance Flood	Tolerance Shade	Seed ripening	Seed storage requirements[1]
Holly, American *Ilex opaca*	Minor stream bottoms and on high ridges of oldest alluvium.	WT	VT	Sept. - Oct.	Store in sealed container.
Honeylocust *Gleditsia triacanthos*	Scattered in large bottoms on all sites except swamps and sloughs. Grows best on the better ridges of new alluvium.	MT	I	Sept. - Oct.	Seeds will retain viability for several years when stored in sealed containers at 32-45 °F (0-7 °C).
Hophornbeam, eastern *Ostrya virginiana*	Slopes and ridges, occasionally in bottoms.	I	T to VT	Late Aug. - Oct.	Unknown.
Hornbeam, American *Carpinus caroliniana*	Rich, moist loams.	MT	VT	Aug. - Oct.	Store at 35-49 °F (2-9 °C) in moist sand, sand and peat, or soil for up to 2 years.
Magnolia, southern *Magnolia grandiflora*	On old alluvium and outwash areas. More common in minor or secondary stream bottoms, hummocks, and wet flats.	WT	T	July - Oct.	Store in sealed containers at 32-41 °F (0-5 °C). Seeds stored at higher temperatures should not be cleaned.
Maple, Florida *Acer barbatum*	Drained sites in secondary bottoms.	WT	T	March - April	Unknown.
Maple, silver *Acer saccharinum*	On riverfronts and stream-banks on moderately well-drained loams.	MT	I to T	April - June	Air dry to 30% moisture content before storage.
Maple, swamp red *Acer rubrum*	Common on low, wet flats and edges of headwater swamps.	MT	T	April - June	Air dry to a moisture content of about 10-15% before storage.
Mulberry, red *Morus rubra*	Common on heavy, moist but well-drained soils in first bottoms.	WT - I	T to VT	June - Aug.	Store dry seeds at subfreezing temperature of about -10 to 0 °F (-23 to -17 °C).
Oak, bur *Quercus macrocarpa*	On better flats and low ridges of older alluvium and tributary bottoms north of latitude of Memphis. Commonly found on limestone ridges.	I	WT	Aug. - late Nov.	White oak group
Oak, cherrybark *Quercus pagoda*	Widely distributed on the best loamy sites on all river-bottom ridges and all better drained creek bottoms and hammocks. Predominantly on older alluvium.	WT - I	I	Sept. - Nov.	Red oak group
Oak, delta post *Quercus stellata* var. *mississippiensis*	Large bottoms of the lower Mississippi River. Well-drained, silty clay and loam sites on older alluvium.	WT - I	WT	Sept. - Nov.	White oak group

Reproductive characteristics	Direct seeding	Waterfowl food	Deer/turkey food	Neotropical migrant	Wood products
Seedlings occur in understory and openings. Sprouts well from stumps.	I	L	L	I	L
New seedlings are usually found in openings and rarely in the understory. Sprouts well from stumps.	I	L	L	H	L
Seedlings establish best on moist mineral soil in understory and in openings. Sprouts well from stumps of all sizes.	I	L	L	I	L
Seedlings establish best on moist mineral soil in understory and in openings. Sprouts well from stumps of all sizes.	I	L	L	I	L
Usually good seed crops but low germination. Sprouts well from stumps.	I	L	L	M-H	L-M
Germinates best on moist mineral soil in shade or openings. Sprouts well from stumps.	I	L	I	I	L
Seedlings occur on bare mineral soil in shade or especially in openings. Sprouts well from stumps.	I	L	H	I	M
Germinates best on moist mineral soil in shade or openings, often after water recedes. Sprouts well from stumps.	I	L	M	I	L
Seedlings occur in shade or openings. Sprouts well from stumps.	I	L	M-H	H	M
Germination may be prolific in open bottomland areas. Seedlings are often killed if flooded during the growing season. Sprouts well from stumps and following burning of small trees, but the quality of sprouts is usually poor.	I	L	H	I	H
Good regeneration with full light but never prolific. Poor quality stump sprouts.	H	H	H	I	H
Good regeneration with light but seldom prolific. Seedlings most common in openings. Not a good stump sprouter.	I	I	H	I	H

Species Name	Habitat	Tolerance		Seed ripening	Seed storage requirements[1]
		Flood	Shade		
Oak, laurel (diamondleaf) *Quercus laurifolia*	Near the coast on wet flats, margin of swamps, low clay ridges, or even low sandy loam ridges of blackwater streams.	WT - MT	I - T	Sept. - Oct.	Red oak group
Oak, live *Quercus virginiana*	Usually in well-drained loams and sandy soils along the coast but also may occur in heavier clays.	WT - T	I	Sept. - Dec.	White oak group
Oak, Nuttall *Quercus nuttallii*	Flats, low ridges, shallow sloughs, and margins of swamps in recent alluvial sites, and heavy, poorly drained clays and clay loams. Strictly limited to bottoms of major streams entering the gulf and their larger tributaries.	MT	I	Sept. - Oct.	Red oak group
Oak, overcup *Quercus lyrata*	Widely distributed on poorly drained, heavy soils of major alluvial bottoms. Prevalent in sloughs, on margins of swamps, and in backwater areas.	MT	WT	Sept. - Nov.	White oak group
Oak, pin *Quercus palustris*	In first bottoms and terraces on wet flats with heavy, poorly drained to moderately well-drained clays or clay loams.	MT	I	Sept. - Dec.	Red oak group
Oak, Shumard *Quercus shumardii*	Restricted to well-drained ridge soils in older alluvium and outwash from uplands and to well-drained creek bottoms and hammocks.	WT	I	Sept. - Oct.	Red oak group
Oak, swamp chestnut *Quercus michauxii*	Common in large creek bottoms and hammocks on best, well-drained loamy ridges. Occasionally on a wet, silty clay, high flat.	WT	I to WT	Sept. - Oct.	White oak group
Oak, swamp white *Quercus bicolor*	Extreme northern part of the lower Mississippi Valley, mainly in smaller bottoms on sites with pervious but poorly drained mineral soils.	MT	WT	Sept. - Oct.	White oak group
Oak, water *Quercus nigra*	Widely distributed on loam ridges in first bottoms and on any ridge and silty clay flats in second bottoms or terraces. Moderately well-drained silty clays and loams.	WT - MT	I	Sept. - Nov.	Red oak group

Reproductive characteristics	Direct seeding	Waterfowl food	Deer/turkey food	Neotropical migrant	Wood products
Regeneration erratic but plentiful with light. Seedlings establish in shade or openings but require release. Sprouts when cut or burned.	I	H	H	I	L
Germination best on moist, warm soil. Sprouts well from roots.	M	H	H	I	L
Acorns remain viable in water for up to 311 days. Seedlings establish in openings or shade but die soon under shade. Seedlings are killed by flooding during the growing season. Stumps of young trees sprout readily.	H	H	H	I	M
Germination is best on moist mineral soil in open or shade but dies under continued shade. Seedlings may be killed by high water during first growing season. Sprouts from small stumps only.	M	M	H	I	L
Seedlings become established in understory openings, but many are killed by flooding during the growing season. Seedlings among most tolerant of oaks. Sprouts well from stumps of small trees.	H	H	H	I	L
Seedlings establish best in full light. Overall poor quality of sprouts but better on young trees.	H	M-H	H	I	H
Germination best on moist, well-drained soils with light cover of leaves. Seedlings require full sunlight for best development. Seedlings are intolerant of flooding. Sprouts from small stumps.	M	M	H	I	H
Regeneration is adequate to sparse, never prolific. Sprouts well from stumps.	I	I	M	I	M
Seedlings establish best on moist, well-aerated soil under leaf litter. Prolonged submergence of seedlings during the growing season is fatal. Sprouts readily from young stumps.	H	H	H	I	M

Species Name	Habitat	Tolerance		Seed ripening	Seed storage requirements[1]
		Flood	Shade		
Oak, white *Quercus alba*	Widely distributed on well-drained loams of the oldest alluvium. Common in better drained creek bottoms above the lower Coastal Plain.	I - WT	WT	Sept. - Nov.	White oak group
Oak, willow *Quercus phellos*	Widely distributed on ridges and high flats of major streams. Less common in creek bottoms. Moderately well-drained silty clays and loams.	WT - MT	I	Aug. - Oct.	Red oak group
Pawpaw *Asimina triloba*	Rich soils along streams and in bottoms.	I	VT	Aug. - Sept.	Unknown.
Persimmon, common *Diospyros virginiana*	Scattered widely on wet flats, shallow sloughs, and swamp margins on poorly drained clays and heavy loams. Rare in creek bottoms.	MT	VT	Sept. - Nov.	Clean, dry seeds should be stored in sealed containers at 41 °F (5 °C).
Poplar, yellow *Liriodendron tulipifera*	Mainly on high quality, well-drained terrace site and outwashes of minor streams. Not primarily a bottomland species.	I	I to VI	Aug. - Oct.	Store dried seeds in sealed cans or plastic bags at 36-40°F (2-4°C) for 3 to 4 years. Moist storage in outdoor soil pits or drums of moist sand in cold storage at 36°F (2°C).
Possumhaw *Ilex decidua*	Margins of swamps, streams, and in rich upland soils.	MT	VT	Early autumn	Unknown.
Sassafras *Sassafras albidum*	Scattered widely on any well-drained site, especially moist but well-drained sandy loam soils.	I	I	Aug. - Sept.	Store in sealed containers at 35-41° (2-5 °C).
Sugarberry *Celtis laevigata*	Common on flats and river fronts of new alluvium but not in deep swamps.	MT	T to VT	Sept. - Oct.	Store in sealed container at 41°F (5°C) for up to 5 ½ years without losing viability.
Swampprivet *Forestiera accuminata*	Swamps, wet flats, and other low lying areas.	T	T	Summer	Unknown.
Sweetgum *Liquidambar styraciflua*	On almost all but the wettest sites. Best developed on clay loam ridges of newer alluvium.	MT	I	Sept. - Nov.	Store at a moisture content of about 10-15% in sealed bags at 35-40 °F (2-4 °C) for up to 4 years.

Reproductive characteristics	Direct seeding	Waterfowl food	Deer/turkey food	Neotropical migrant	Wood products
Germination best on moist, well-drained soil under direct light. Seedlings intolerant of flooding. Sprouts well from stumps and following fire damage.	M	H	H	I	H
Germination best in full light on moist, well-aerated soil with light leaf litter. Sprouts from young stumps.	H	H	H	I	M
Seedlings establish well in shade or openings. Sprouts well from stumps.	I	L	I	I	L
Seedlings establish mainly in the understory but also in openings. Sprouts readily from stumps and roots.	I	L	H	I	M
Seedlings establish best on moist seedbeds of exposed mineral soil and survive only in full sunlight. Seedlings cannot tolerate flooding. Sprouts readily from stumps.	I	L	L	I	H
Seedlings occur in understory and especially in partial openings. Sprouts well from stumps.	I	L	L	H	L
Germination sparse but is best on moist, loamy soil with litter. Grows well in openings. Sprouts well from roots and stumps.	I	L	L	M-H	L
Seedlings often become established in full shade but cannot withstand submergence. Sprouts well from stumps up to 30 cm (12 inches).	I	L	L-M	H	M
Germination is best in moist mineral soil. Sprouts well from stumps.	I	L	L	I	L
Germination is best on mineral soil in the open. Sprouts well from roots and stumps.	I	M	L	H	M

Species Name	Habitat	Tolerance: Flood	Tolerance: Shade	Seed ripening	Seed storage requirements[1]
Sycamore *Platanus occidentalis*	Widely distributed on fronts of major streams and on banks of minor streams, generally on moderately well-drained loams.	MT	WT to I	Sept. - Oct.	Short-term storage in ventilated open-mesh bags. For longer storage, dry to 10-15% moisture content and store in sealed containers at 20-38°F (-7 to 3°C).
Tupelo, Ogeechee *Nyssa ogeche*	Limited to backwater streams and coastal swamps.	T	I	July - Aug.	Store over winter in cold, moist sand or in cold storage.
Tupelo, swamp *Nyssa sylvatica* var. *biflora*	Nonalluvial muck and coastal swamps, seepage areas of upland, and on edges of secondary and minor bottoms.	T	I to WT	Aug. - Oct.	Store over winter in cold, moist sand or in cold storage.
Tupelo, water *Nyssa aquatica*	Swamps and floodplains of alluvial streams.	VT	I to WT	Sept. - Oct.	Store over winter in cold, moist sand or in cold storage.
Walnut, black *Juglans nigra*	Scattered on well-drained loamy sites, typically a creek bottom species.	WT	I	Sept. - Oct.	Clean seed, 20-40% moisture content at 37°F (3 °C) for 1 year in plastic bags or 50% moisture content in screen container buried in pits for up to 5 years.
Waterlocust *Gleditsia aquatica*	Swamps, sloughs, and wet flats.	MT	I	Aug. - Oct.	Seeds will retain viability for several years when stored in sealed containers at 32-45 °F (0-7 °C).
Willow, black *Salix nigra*	Margins and batture of sloughs of principle rivers, also on ditch banks and swamp margins.	T	VI	June - July	Wet seeds may be stored up to a month if refrigerated in a sealed container.
Willow, sandbar *Salix exigua*	Along river margins, on newly formed, low bars and towheads.	MT	VI	Apr. - May	Wet seeds may be stored up to a month if refrigerated in a sealed container.

[1] See seed handling section, Chapter 6, for information on seed drying. Seeds from the white oak group generally should not be stored due to loss of viability. Seeds from the red oak group can be stored for up to about 6 months. Seed storage for longer than 6 months should be dry, in sealed containers at 32-36 °F (0-2 °C), but viability loss will be significant.

Reproductive characteristics	Direct seeding	Waterfowl food	Deer/turkey food	Neotropical migrant	Wood products
Seedlings establish best on moist mudflats or other exposed mineral soils, never in shade. Seedlings remain viable in water for 1 month. Sprouts well from stumps.	I	L	L	I	M
Germination and establishment occurs in openings on bare mud when the water recedes.	I	M	M	I	L
Germination best in openings on moist seedbed. Seeds remain viable for months in water. Sprouts well from stumps. Sprouts produce viable seed within 2 years.	I	L-M	L-M	I	L-M
Need full sunlight for germination. Seeds remain viable for months in water. Stump sprouts produce viable seeds within 2 years.	I	L-M	L	I	L-M
Seedlings are mainly found in forest openings but are intolerant of flooding. Sprouts well from small stumps.	I	L	L	I	H
New seedlings are usually found in openings and rarely in the understory. Sprouts well from stumps.	I	L	M	I	L
Germination best on very moist, exposed mineral soil. Seeds will germinate in water. Sprouts well from stumps of small trees. Intolerant of competition.	I	L	H	M-H	M
Germination best on very moist, exposed mineral soil. Seeds will germinate in water. Seedlings more flood tolerant than mature trees. Sprouts well from stumps of small trees. Intolerant of competition.	I	L	H	I	L

An inherent difficulty with using either reference wetlands or reference forest ecosystems is that forested wetland restoration projects are long-term efforts. Thus, many years will pass before the restoration project can be compared to the reference. Still, the process of characterizing similar natural wetlands in the vicinity of the restoration site is useful for species selection and for developing success criteria (see Chapter 2).

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